

Chapter 5 Pumping Equipment

5-1. General

The following types of centrifugal class of pumps are used for flood-protection pumping stations:

a. Axial-flow impeller type.

- (1) Fixed-blade, vertical type.
- (2) Adjustable-blade, vertical type.
- (3) Fixed-blade, horizontal type.

b. Mixed-flow impeller type.

- (1) Fixed-blade, vertical type.
- (2) Volute type.

c. Centrifugal volute or radial-flow type.

The type that should be used for any particular installation is dependent upon the service conditions, head requirements, and station layout. Chart B-1, Appendix B, shows the approximate useful range of capacity and head for each type of pump that is described. The appropriate pump type should be chosen only after a detailed study of the possible choices.

5-2. Pump Characteristics and Types

a. General.

(1) Pumps are usually classified by their specific speed. Specific speed is defined as the speed a pump would have if the geometrically similar impeller were reduced in size so that it would pump 1 gallon per minute (gpm) against a total head of 1 foot. In SI, N_s is called type number with Q in liters per second and H in meters. Specific speed is expressed as:

$$N_s = N_t (Q^{0.50}) / H^{0.75} \quad (5-1)$$

where

N_s = pump specific speed

N_t = pump rotative speed, revolutions per minute (rpm)

Q = flow at optimum efficiency point, gpm

H = total head at optimum efficiency point, feet

(2) Suction specific speed is a dimensionless quantity that describes the suction characteristics of a pumping system, designated as available, or the suction characteristics of a given pump, designated as required. The suction specific speed required must exceed the suction specific available to prevent cavitation. The suction specific speed available, based on the lowest head pumping condition, is often used to determine the maximum permissible speed of the pump.

$$S = N_t (Q)^{0.5} / (NPSHA)^{0.75} \quad (5-2)$$

where

S = suction specific speed available

N_t = pump rotative speed, rpm

Q = flow rate, gpm

$NPSHA$ = net positive suction head available, feet

b. Axial flow. The impellers of these pumps have blades shaped like a propeller. This type of pump develops most of its head by lifting action of the blades on the liquid. The pumped fluid travels in a direction parallel to the shaft axis, hence the name "axial flow." It can also be constructed as an adjustable blade pump in which the pitch of the blades is varied to provide different pumping rates and/or reduced starting torque. Axial flow pumps are primarily used to pump large quantities of water against low heads and are typically used in open sump pumping stations in a vertical configuration. The value of N_s for this type of pump is typically above 9,000.

c. Mixed flow. The impeller of these pumps develops head or discharge pressure by a combination of both a lifting action and a centrifugal force. The path of flow through the impeller is at an angle (less than 90 degrees) with respect to the pump shaft. This pump can be constructed with multistages; however, for most Corps stations, a single stage will develop sufficient head to

satisfy most head requirements. The pump can be constructed similar to an axial flow pump with water flowing axially from the pumping element, or the impeller can be placed in a volute (spiral casing), where the water flows from the pump radially. The volute design would be used either for large pumps where a volute would allow the pump to operate at lower heads or for small pumps where it is desirable to have a dry pit installation with the discharge pipe connected near the pumping element. The value of N_s for this type of pump should be limited to 9,000.

d. Centrifugal. The impeller of these pumps develops head only by centrifugal force on the water. The path of flow through the impeller would be at a 90-degree angle with respect to the pump shaft. A special design of this pump has a non-clog impeller which makes it very useful for pumping sewage. This type of pump is used for pumping small flows and in applications where a dry pit sump is desirable. It is generally used in a vertical configuration and can be constructed to operate in a wet or dry sump. The value of the N_s is typically less than 4,000.

e. Net positive suction head. This term is used to describe the suction condition of a pump; it is commonly abbreviated with the letters NPSH. Two forms of NPSH are used. One is used to describe what suction condition is available to the pump and is called Net Positive Suction Head Available (NPSHA), and is a function of the station layout and suction water levels. NPSHA is defined as the total suction head in feet of liquid absolute, determined at the suction nozzle and referred to datum, less the absolute vapor pressure of the liquid in feet of liquid pumped. See Appendix B for formula and terms used. The other term Net Positive Suction Head Required (NPSHR) is a property of the pump and indicates what suction condition is required for the pump to operate without cavitation. NPSHR is determined by the pump manufacturer by running cavitation tests on the pump.

5-3. Pump Arrangements

a. Vertical. Most pumps used in flood-control pumping stations are of the vertical type. This type of pump has a vertical shaft with the driver having a vertical or horizontal shaft arrangement. A vertical motor is usually direct connected to the pump, whereas a horizontal motor or engine requires the use of a right-angle gear. The vertical arrangement usually requires the least floor space per unit of pumping capacity. While the vertical

motor could cost more than the right-angle gear reducer and higher speed horizontal motor combined, the decreased reliability and increased operation and maintenance costs due to the additional auxiliary equipment involved may offset the first cost savings. One problem associated with a vertical pump layout is that the pump dimensions may locate the discharge elbow higher than the minimum head required by hydraulic conditions. The higher head will require greater energy. Other type layouts such as a siphon discharge or volute, horizontal, and flower pot type pumps will permit lower minimum heads or in the case of a siphon only the discharge system losses. Vertical pumps are used with open or closed sumps, wet or dry, and are suspended from an operating floor or an intermediate floor.

b. Horizontal. Horizontal type pumps are usually limited to applications where the total head is less than 6 meters (20 feet) and the quantity of water to be pumped is large. Horizontal pumps are seldom less than 2,500 millimeters (100 inches) in diameter. Smaller horizontal pump installations are generally more expensive than vertical installations. The pumps are not self-priming, and the design must provide a separate priming system.

c. Formed suction intake. Formed suction intakes are not really a pump type but are suction arrangements that generally improve flow conditions to the pump. They are applied to vertical pumps and are used in place of the standard bell arrangement. Typical dimensions of a formed suction intake are shown in Figure B-12, Appendix B.

d. Submersible.

(1) General. Submersible pumps are considered for stations that have pumping requirements with each pump having a capacity less than 6 m³/s (200 cfs). These pumps have the electric motor close coupled to the pumping element with the entire pumping unit being submerged in water. The size and selection of these units are limited by the number of poles in the motor or the size of the gear unit, if used, and its resultant encroachment on the water passage. These types of pumps should be removable from above the floor without any unbolting of the discharge piping. Their use allows the superstructure of the station to be greatly reduced. Substructure requirements are approximately the same as for vertical pumps. Submersible pumps used for flood control pumping stations are of three different types: axial flow, mixed flow, and centrifugal volute.

(2) **Axial or mixed flow.** These pumps consist of an axial- or mixed-flow impeller close coupled to a submersible electric motor. The impeller may be on the same shaft as the motor or a set of gears may be between the motor and the impeller to permit greater variety of speed. The pump is suspended above the sump floor inside of a vertical tube that extends to the operating floor. The tube allows placement and removal of the pump and forms part of the discharge piping. These pumps are used in a wet pit-type sump. Some pumps of this design are constructed so that the blades are detachable from the propeller hub and are connected to the hub in a manner that allows a multitude of blade angle settings. The blade angle adjustment feature also permits changing the pump performance characteristics very easily. This permits a pump installation to meet a different future hydrology condition with adjustment of the blade angle.

(3) **Centrifugal.** These pumps consist of a volute casing close coupled to a submersible electric motor. The impeller and motor are on the same shaft. The pumping unit is guided to its operating position from the operating floor level by a system of guide rails or cables. The volute attaches to the discharge piping flange by means of a bracket using the weight of the pump to seal the connection. These pumps are used for smaller flows than the axial- or mixed-flow type and when pumping heads are high. These pumps are also suitable for use in a dry pit sump. These pumps are usually equipped with a water jacket surrounding the motor to cool the motor with pumped fluid. For special applications, these pumps can also be fitted with a different diffuser which allows them to be tube mounted similar to the axial-flow submersible pumps.

5-4. Selection of Pump Type

a. General. Many items must be considered during the pump selection process. Alternative station layouts should be developed in sufficient detail so that an annual cost of each layout over the life of the project can be determined. The annual cost should include the annualized first cost, operating costs which include cost of energy, maintenance, and replacement costs. It is usually best to consider all of the above types of pumps when developing the station layout unless it is obvious that certain ones are not applicable. The station layout and pump selection should be done in sufficient detail to permit the reviewer to follow the process without reference to additional catalogs or other such sources.

b. Capacity. The capacity requirement for the pump is determined from the hydrology requirements of the station. This information is provided by the H&H engineers. The number of pumps used should be kept to a minimum and determined as set forth in EM 1110-2-3102. If more than one capacity requirement exists, the pump is selected to satisfy all of the conditions. This means that the pump will most likely be over capacity for some of the requirements. Variable capacity pumping units may be economically justifiable. Variable capacity can be achieved by using variable speed drives or pumps that are equipped with variable pitch blades.

c. Head. The head requirements of the pump are also determined from the hydrology requirements plus the losses in the pumping circuit which are a function of the station layout. The pump head requirement is called total head and is a summation of all heads for a given capacity. The method of computation of these heads is included in Chapter 6. Selection of pumps should strive to achieve the lowest total head requirement to provide the smallest size driver and lowest energy cost. The best pump operation occurs when the pump is operating at or near the head that occurs at the pump's best efficiency point. With the wide range of heads that occur for flood-control pumping stations, this is usually not possible. The pump must be selected to satisfy all the required conditions. However, if a choice exists, the pump should be selected so that the best efficiency point is near the head where the most pumping operation occurs. Some pumps, particularly the axial flow type, may have a curve which contains what is called a "dog-leg." This part of the curve consists of a dip in head which allows the pump to operate at as many as three different pumping rates, all being at the same head. Pump operation and priming at this head must be avoided due to unstable operation.

d. Net positive suction head. The suction conditions available for the pump should be determined for all pumping conditions. A diagram should be prepared showing the NPSHA for the entire range of pumping conditions. The method of computation of the NPSHA is shown in Appendix B. The NPSHA should meet the margins and limits indicated in Appendix B. In all cases the NPSHA should be greater than the NPSHR for the selected pump over the entire range of required pump operation. Pumps not requiring the cavitation tests should be specified to meet the suction limits developed over the entire range of required pump operation and the suction limit criteria as indicated in Appendix B.

e. Efficiency. Higher efficiencies available from the different types of pumping units are a consideration when the estimated amount of operation is great enough to affect cost considerations. Usually for stations with capacities less than 14 m³/sec (500 cfs) and operating less than 500 hours per year, differences in operating efficiencies of various types of pumping equipment need not be considered. The highest efficiency that is commercially attainable should be specified for whatever type of pump is selected. This will not only control operating costs but will normally improve the operation of the pump through less vibration, cavitation, and maintenance requirements.

f. Other considerations. Certain limitations sometimes guide pump selection.

(1) Incoming electric service. Incoming electric service may limit the horsepower rating of the driver or may not permit the use of electric motors.

(2) Foundation conditions. Foundation conditions may increase the cost of excavation to the point where it may not be feasible to lower the sump to that required for some types of pumps.

(3) Available space. The available space at the proposed station site may limit the size of the station.

(4) Low discharge capacity. Axial- and mixed-flow pumps may have too small flow passages and would therefore be subject to clogging. A centrifugal pump would then be used because of its greater solid passing capability.

g. Selection procedure. The first step in developing a pump selection is to determine the approximate pump operating conditions. Total heads used for these approximate operating conditions can be determined from adding the static heads (discharge pool level or pump discharge elevation minus the lowest pump suction level) to an approximation of the system losses plus the velocity head. Use the capacities from the hydrology requirements, the approximate total heads, and Chart B-1 in Appendix B to determine the types of pump that may be

suitable for the conditions. Using each pump type selected from the chart, a pump selection is made using the method indicated in Appendix B. A station layout for each type of pump can be developed. Dimensions for the pumping equipment and sump dimensions can be obtained from the procedure given in Appendix B. It may be necessary to refine the heads and therefore the station layout due to changes in head when the equipment is selected and located in the station. The information from the final pump station layout should be sent to a minimum of two pump manufacturers requesting their selection of recommended pumping equipment for the given station layout. It is important that the communication with the pump manufacturers takes place during the design memorandum phase of the project. See Chart B-3 in Appendix B for a typical pump manufacturer data sheet. The information thus obtained should be used to correct, if necessary, the station layout and finalize the alternate study layouts and costs. Operation, maintenance, and equipment replacement costs must also be considered in the selection of the type of station to use. Operation costs should consider the cost of energy and operating labor when the station is in operation. In some cases, these costs are very small due to limited operation and the detail in those cases can be limited. When the estimated operating costs for a station exceed \$10,000 per year, it could be necessary to use a detailed energy cost analysis based on pump head, cycling effect, and any special considerations the supplier of the energy may require. Maintenance cost should be carefully considered since it goes on whether the station is in operation or not. The tendency is to underestimate this expense. Discussion with the eventual user could aid the designer in determining the maintenance methods that will be used. Replacement costs should be based on both wear out and obsolescence of the equipment. Equipment replacements are also made when the cost of maintenance becomes excessive and the reliability of the equipment is in doubt. Equipment manufacturers usually provide the expected life of their equipment while operating under normal conditions. When equipment operation will occur beyond the normal conditions, as defined by the manufacturer, the expected life should be adjusted accordingly. Selection is then based on annual costs and reliability factors.